

# **Radar Remote Sensing of Waves and Currents in the Nearshore Zone**

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## **LONG-TERM GOALS**

Our long-term goal is to contribute to our understanding of processes in the upper ocean and lower atmosphere through the conception, development, and application of novel microwave, acoustic, and optical remote sensing techniques.

## **OBJECTIVES**

The objectives of this effort are to determine the extent to which Doppler radar techniques are useful for nearshore remote sensing applications. Of particular interest are estimates of surf zone location and extent, surface currents, waves, and bathymetry. To date, optical (video) techniques have been the primary remote sensing technology used for these applications. A key advantage of the radar is its all-weather day-night operability.

## **APPROACH**

We deployed two Doppler radar systems adapted from commercial high-seas navigation radars during the 2003 Nearshore Canyon Experiment (NCEX). The modified marine radars systems were deployed during NCEX to provide synoptic images of the incident wave fields and surface currents through measurement of backscattered power and Doppler velocities. This work continues prior efforts using the FOPAIR imaging radar to further our understanding of radar backscatter from nearshore breaking waves and inter-bore processes (*Puleo et al., 2003; Farquharson et al., 2005*).

During NCEX, one radar was deployed atop the NOAA Southwest Fisheries Science Center, and the other above the Black's Beach access road. Both time-resolved and time-averaged radar imagery are analyzed to deduce nearshore properties with intercomparisons with available in-situ and video observations. Our analysis efforts focus on the first three moments of the Doppler spectrum: backscattered power, mean Doppler velocity, and Doppler spectrum width. Finally, our experience with modifying commercial marine radars for NCEX has also motivated development of a truly coherent low-peak-power Doppler radar for nearshore applications.

## **WORK COMPLETED**

A manuscript was completed and published (*Farquharson et al., 2005*) which detailed observations of radar scattering from surf zone bores and compared radar measured velocity fields with in-situ

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observations by WHOI (Raubenheimer, Elgar). Further details of this study are available in our FY05 annual report.

NCEX radar data from the unit on the SWFSC has been processed to ten-minute time-averaged imagery of power, mean velocity, and coherence (the correlation coefficient between pairs of pulses used to calculate Doppler velocity). These data have been georeferenced into the Scripps Argus coordinate system and images have been posted to our NCEX web archive at <http://abyss.ecs.umass.edu/ncex/>. At present, data posted is limited to the few days with significant winds offshore. Initial comparisons of surf zone radar observation with video are underway in collaboration with Ohio State University (Lippmann – see next section).

Design and construction of a low-power, solid-state Doppler radar was completed (*Perkovic et al., 2006*), and testing is underway.

## RESULTS

Figure 1 shows ten-minute time exposures of three radar data products collected on 31 Oct 2003 at 1600 GMT (0800 PST) and referenced to the Scripps Argus coordinate system. The left panel shows the time-averaged radar backscatter which is analagous to a video intensity time exposure. Strong echoes are evident from breaking waves, bores, and white water in the surf zone as well as from hard targets (e.g. buoys) offshore. There is some evidence of a rip current at (x,y) coordinates (400,-1200) where foam ejected from the surf zone extends into the offshore region.

The middle panel shows time-averaged Doppler velocity. At all locations, Doppler velocity is the line-of-sight component of the surface velocity with respect to the radar location (upper left corner of the image). Within the surf zone, this line-of-sight component is very nearly alongshore. Blue indicates mean velocities towards the radar while red indicates velocities away from the radar and white indicates zero velocity. Velocities have been zeroed out in regions of low backscatter (lower left) of the image. We find that a strong convergence in the Doppler velocity corresponds to the rip location. At that location, the simultaneous presence of advancing velocities in the outer portion of the surf zone and receding velocities at the inner portion is suggestive of an eddy.

The preponderance of receding (red) velocities in the offshore region is a consequence of the radar scattering mechanism in the open water. Here, the phase velocity of Bragg scattering ripples and wind-induced drift yield a mean velocity in the neighborhood of 50 cm/s. This velocity observation is consistent with the orientation of "wind streaks" evident in the backscatter image (these correspond to regions of surface convergence where surfactants accumulate which suppress the roughness needed for radar echo). In the surf zone, the sheltering effect of the nearby cliffs reduces the impact of wind-driven surface roughness. Also, as the roughness in the surf zone is primarily mechanically generated, the influence of wind is believed to be small.

The right panel shows the radar coherence, defined as the correlation coefficient of echoes between successive radar pulses. Values near unity indicate highly correlated samples and a well defined velocity, while low values indicate less correlation and larger uncertainty in the mean velocity. Thus the coherence is indicative of the distribution of radial velocities observed at a given point. In the coherence image, the outer edge of the surf zone is characterized by a narrow band of values near unity. At present, we believe this to be attributable to the scattering from the steepening waves just prior to breaking. The coherence is reduced within the surf zone, where the broken waves, bores, and white water yield a wider velocity distribution. Offshore, the coherence is low due to the low signal-

to-noise ratio. Elevated coherence is observed where foam is ejected from the surf zone by the rip current. It is more prominent in this image than in the backscatter image. Finally, the locations of the in-situ instruments appear most prominently in this image (actually warning flags protruding from the water). We note the radar coherence image appears most similar to variance imagery produced by video remote sensors.

Figure 2 shows a preliminary comparison of NCEX radar results with video PIV-derived velocities (Lippmann, OSU). The left panel shows the same radar backscatter image from Figure 1. Superimposed on the image are the locations of cross-shore transects where video PIV velocities were successfully computed. These locations match up very well with the region of high intensity scattering attributed to the surf zone by the radar. The right panel shows a scatter plot of 10-minute mean Doppler velocities with the radial component of corresponding 9-minute PIV velocities at *all* the locations shown. Though significant scatter is evident between the two independent measurements of the surface velocity, a correlation with the proper slope clearly exists. We have not performed any conditional sampling of the data in this comparison, so a variety of factors may be contributing to the observed scatter. We have separately established qualitative agreement of features in the velocity field observed by both video PIV and by the radar. Future effort will be directed towards careful comparison of the velocity fields and other remotely sensed products.

## **IMPACT/APPLICATIONS**

Doppler radar offers day-night all-weather monitoring of surf zone and nearshore conditions from standoff distances.

## **RELATED PROJECTS**

The first scientific results (*Toporkov et al., 2005*) were published from test flights of the Dual-Beam Interferometer, an interferometric SAR for sea-surface current measurement developed by the PI at the University of Massachusetts (*Farquharson et al., 2004*). Vector tidal currents near inlets in barrier islands along the Florida gulf coast were successfully mapped with the radar deployed in a wing-mounted pod. Results of these flights were featured on the cover of the Nov. 2005 issue of *IEEE Transactions on Geoscience and Remote Sensing* and won an NRL Alan Berman Research Publication Award.

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## **PUBLICATIONS**

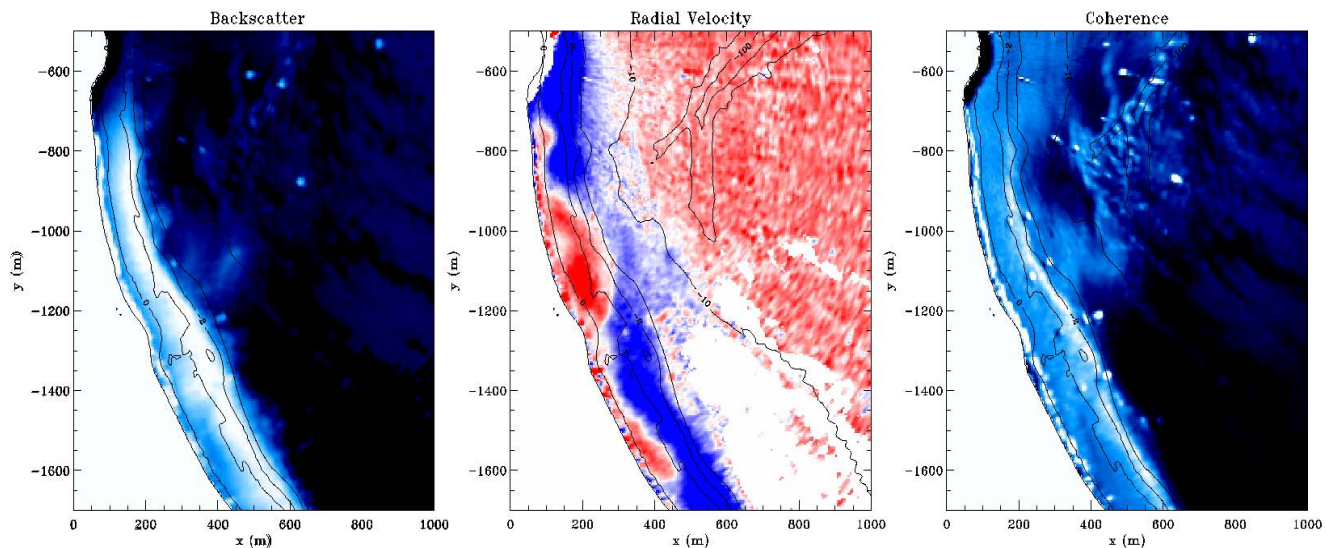
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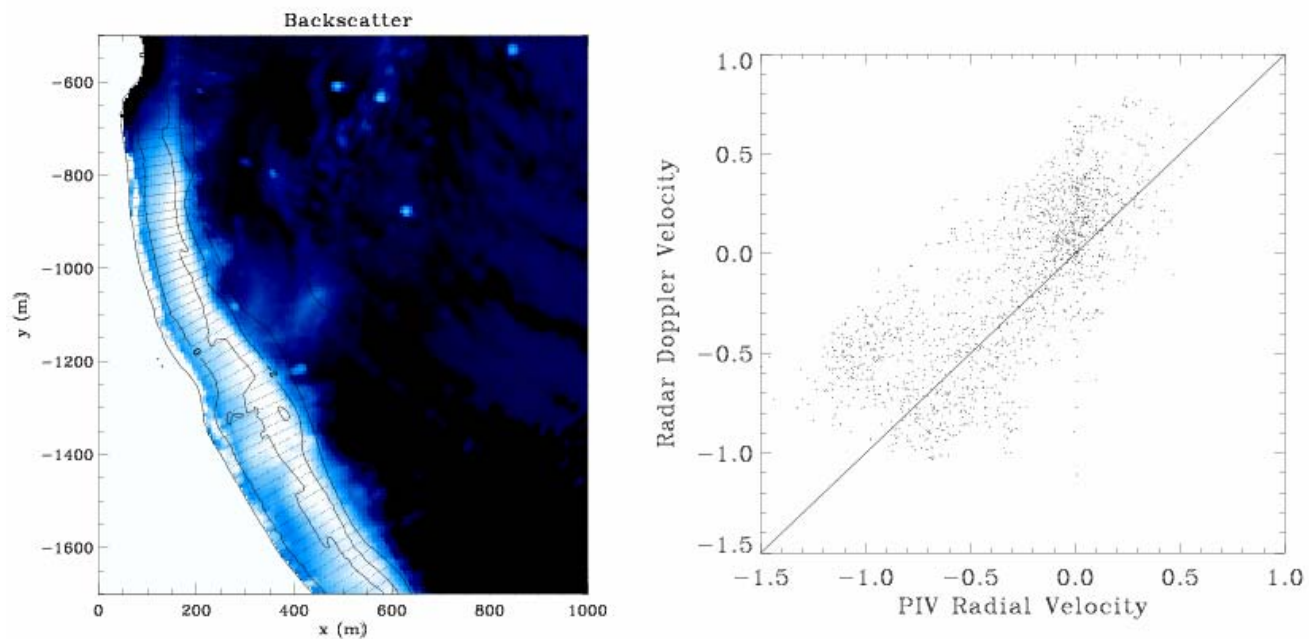
Perkovic, D., G. Pathak, S.J. Frasier, 2006. "Solid-State Doppler Radar for Remote Sensing of Nearshore Waves and Currents", *Eos Trans. AGU*, **87**(36), Ocean Sci. Meet. Suppl., Abstract OS34O-06.

## **HONORS/AWARDS/PRIZES**

2005 Alan Berman Research Publication Award, for *Toporkov et al., 2005*.



**Figure 1:** Ten-minute time exposures of Doppler radar data collected over Scripps Canyon and Black's Beach on 31 Oct 2003 at 1600 GMT. Radar location is upper left corner. Left: Mean radar backscatter intensity (30 dB range). Center: Mean radial velocity where blue corresponds to -0.5 m/s (advancing) and red to 0.5 m/s (receding). Right: Radar coherence indicative of the breaking zone and foam ejected from surf.



**Figure 2:** Left: Mean radar backscatter image with locations of OSU's PIV transects indicated. Right: Scatter plot of 10-minute mean radar Doppler velocities vs. 9-minute PIV radial velocities from all locations indicated in the image at left.